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Controller Design and Stability Analysis of Grid Connected DC Microgrid

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Abstract— **The DC microgrids are desired to provide the electricity for the remote areas which are far from the main grid. The microgrid gets popularity because DC power source such as photovoltaic (PV), battery bank and fuel cell can be interconnected without AC/DC converters. The stochastic nature of PV power and variation in the demand are responsible for voltage fluctuations in the DC microgrids. The voltage stability is a most important issue in case of DC microgrids. The challenging thing is to maintain the microgrid voltage upto a reference value for the variable load. This paper focuses on the designing a controller to obtain the voltage stability of microgrid.**

The two controllers (PI and fuzzy logic PI (FL-PI)) are designed to the voltage stability analysis of DC microgrid. Real-time simulation results show that upon appropriate choice of controller parameters, the DC microgrid voltage can be kept constant regardless of wide range of voltage variations of the source and load. The simulation results show the comparison of two controllers. The FL-PI controller shows much better performance than the conventional PI controller for the DC grid voltage control. With the inclusion of the proposed controllers the controlled voltage will obtained, whatever may be the load and its variation.

***Index Terms*— Microgrids, PI and fizzy-PI controller, voltage stability, photovoltaic, linear, nonlinear.**

NOMENCLATURE

V_{g_ref}	Reference microgrid voltage (volts)
V_{g_m}	Measured microgrid voltage (volts)
P_{DC}	Total DC power (kW)
$P_{pv}(j)$	The power from the PV panel (kW) of j^{th} home
$P_{bb}(j)$	The power from the BB (kW) of j^{th} home
P_{pv_ref}	The maximum power obtained from PV (kW)
i_{dc_ref}	Capacitor current
i_L	Choke current
i_s	The public utility current
i_{bb}	The battery current
i_{pv}	The PV current
V_{est_pv}	The estimated PV voltage
P_{est_pv}	The estimated PV power
i_{est_pv}	The estimated PV current
V_{dc_ref}	The controlled microgrid voltage
P_{dc_ref}	The controlled power
i_{dc_ref}	The controlled current
$\hbar$	Radiance from sun
A	The solar panel area
r	The solar panel yield
Υ	The performance parameter of solar panel
σ	Standard deviation
t	The different time instants of a day
V_t	The simulated volatge at time instant t
V_{tmean}	The mean of the simulated instant volatges

I. INTRODUCTION

In order to ensure the stability of a DC system, the power flow within the DC microgrid must be balanced at all times to ensure the DC voltage to be maintained. As renewable generations, such as wind and photovoltaic power, are obliged to follow the meteorological conditions [1-2], and local loads usually operate on their own merits, the other controllable sources, e.g., energy storage, network connected converters etc., must accommodate their variable demands to balance the power.

There is a need of controlling some parameters to make a power supply balance between the sources and loads. Some studies have been carried out in the area of controlling the DC microgrid voltage [3]. However most of them are related to the droop concept to regulate the grid voltage [4-5]. In a DC system the grid voltage is get affected when there is a change in the load from the consumer side. During the switch ON/OFF the appliance, the load current gets changed and the voltage become unstable from its reference or desired value. Therefore, there is need of good method for the voltage control of DC microgrid.

Some controlling schemes for the line currents compensation are given in literature using the conventional controllers [6-9]. Generally PI controllers are used for the DC voltage controlling [10]. These controllers require accurate and difficult to obtained mathematical models. Due to functional and structure simplicity PI controllers are used most in industrial applications [11]. For the first and second order system the PI controller may give good performance by tuning the parameters but for higher systems the tuning become difficult. The performances of the controllers like PI and PID controllers are affected by the operating conditions of any system means there performances are disturbed by the parameter variations, nonlinearity and load side changes [11]. On the other hand the controllers those are designed by fuzzy logic showing the many advantages over the conventional controllers. Fuzzy control requires the expert knowledge and experience and decision making.

The power from PV generators should be controlled to get the uninterrupted grid services. In [12] a pulse width modulation voltage source inverter (PWM-VSI) has been connected between a DC source, which is supplied from a photovoltaic (PV) array and the AC grid to control the DC-AC converter which is connected to the grid. In [13] reactive power compensation has been provided to improve the utilization factor of the system during night time also. The solution for uninterrupted power supply is given by the integration storage device like battery bank (BB) with the renewable sources so to fulfill the extra demand or to store the excess power generated to use it as backup at the demand time [14-15]. The coordination of power generating sources and storage devices is must to fulfill the demand without interruption. The power balancing and control of storage units also required. In [16] the utilization of the supercapcitors and lead-acid batteries has been done by interconnected them in a DC-coupled structure. The objective of this system is to supply prescribed reactive and active power to the grid. A coordinated use of storage units must be designed within the available renewable resource in order to satisfy the power requirements. The power sharing between different energy devices may leads to a smooth grid voltage as the power fluctuations get balanced. In [17] a control system based on energy management has been discussed which is responsible for the coordination among different sources. The system was designed for the wind generator. While in [18] superconductors are utilizing on the DC bus with the incorporation of UPS properties to supply the large loads. Sometimes a voltage droop based power sharing techniques are used for the smooth grid power flow as discussed in [19-20]. The system should be designed such that it is robust to the power variations. On the other hand a coordinated scheme has been proposed in [21] for the control in the data centers.

All the previous control is not adoptable for the complete DC microgrid with uninterrupted power supply. Proposed scheme in this paper is showing its superiority in terms of its efficiency. Here the objective is to keep the DC microgrid voltage at the reference DC level (i.e. at 124V here). There is a change in the power and load due to demand variations. This change creates fluctuations in the grid voltage level. So there is need of a controller. In this paper, the coordination of the BB with the PV and grid is also discussed. A PI controller is designed for the DC microgrid voltage control. Mean while a fuzzy-PI controller also designed which is taking the advantage of PI experiences and fuzzy knowledge. After that, both controllers are compared based on the performance parameters. This paper presents a system design of DC microgrid voltage control. The DC microgrid voltage controllers (PI and Fuzzy PI) are used to maintain a DC microgrid voltage at a constant value.

Next sections for the paper are as follows. In section II there is a description of proposed microgrid system having multiple power sources. In section III formulation and modeling of DC voltage control has been discussed. Section IV is showing the simulation results obtained from both the controllers and their comparison. Finally section V concludes the paper.

II. System Configuration

The general layout of the proposed DC microgrid system is shown in Fig. 1. The DC bus of the microgrid is connected to the public utility (PU) via AC-DC converter. The microgrid of n-homes connected with the main grid via capacitor (C), which helps in balancing the grid current (i_s). The DC microgrid is consists of n-number of homes (home-1, home-2, home-3,..,home-n). Each home has a battery bank (BB) and PV plant (captive power). The BB and PV plants are interfaced to the DC bus of microgrid via DC-DC converters. On the other hand the capacitors (C_1, C_2, C_3....C_n) connected to every PV panel to control the maximum PV current (i_{pv_ref}). The BB stores the energy for future use, when the PV plant produces the higher power than the demand of the home. The BB feed the energy back to the microgrid when the demand of the home is higher than the PV power production. In this way BBs help to reduce the power in unbalancing in the DC bus. The reference voltage (V_{g_ref}) which has to be maintained is set to be according to US standard at 124 V. The DC microgrid measured voltage (V_{g_m}) is monitored by a voltage sensor mounted on the DC-bus. The first stage power balancing is done by the power sharing from BB and associated controllers manage this task. If the power disturbance is higher and BBs controllers are not able to balance it then the second stage power controlling is done by PU and associated AC-DC converter.

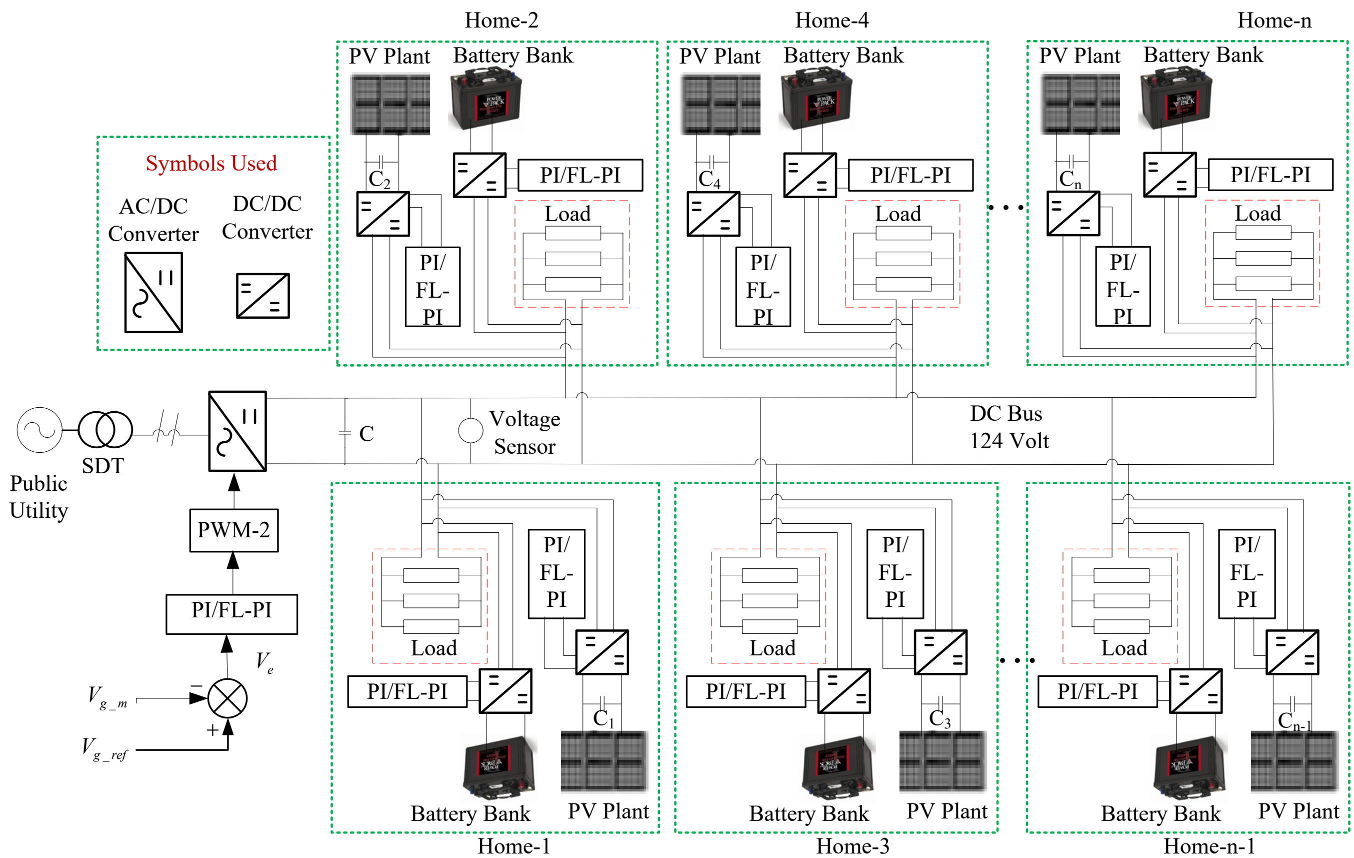

Fig. 1. DC Microgrid Layout for Grid Voltage Control

III. Control Algorithm

Total DC power (P_{DC}) is the sum of all connected sources including storage sources to the respective DC bus. In the proposed configuration there are n-number of homes in the microgrid having n-number of PVs and n-number of BBs. During PU outage, the total power at the DC bus is given by a maximum power point tracking (MPPT) algorithm according to the "power algorithm" level [22]:

$$P_{DC} = \sum_{j=1}^{n} P_{pv}(j) \pm \sum_{j=1}^{n} P_{bb}(j) \tag{1}$$

where, $P_{pv}(j)$ and $P_{bb}(j)$ are the power from the PV panel and BB of j^{th} home respectively.

During the night hours the PV generation is become zero and PV act as an outage sources and if the PU is also acts as outage power source then the BBs will balance the total demand of the microgrid. When the BB is fully charged, the voltage is following the maximum power (P_{pv-ref}), but decreases during the off-PV hours. The BB charging may need to be charge at the time when voltage is below the maximum power point of the PV panel. The current and voltage relation of PV cell is non-linear. The maximum power can be obtained from the PV plant by matching the internal impedance of PV plant and load. It can be achieved by applying maximum power point tracking (MPPT). The above discussed problem can be resolved by applying MPPT for PV. The flow chart describes the MPPT for PV. Every time there is a check for voltage and current. The difference of instant powers is going to check and accordingly the voltage is to be change (increase or decrease). To achieve the DC bus voltage close to the reference voltage, PI or FL-PI controller [23] have to set the capacitor current (i_{dc_ref}) in a closed loop manner. The PV voltage (V_{pv}) is controlled to set the maximum PV power reference (P_{pv_ref}), which is calculated by current controllers used to control the choke current (i_L), the PU currents (i_s), and the BB current (i_{bb}).

Almost all the demand is fulfilled by the PV panels connected in the microgrid specially if there is no grid available. The PV power obtained from of the proposed system is expressed as:

$$\sum_{j=1}^{n} P_{pv}(j) = \sum_{j=1}^{n} V_{pv}(j) i_{pv}(j) \tag{2}$$

where, i_{pv} is the PV current, the PV plant output power of the j^{th} home is the product of the voltage and current of PV plant. The total PV power feed to the microgrid is the algebraic sum of power of PV plants of n-homes.

The total power sharing of BBs with the microgrid is the addition of power sharing with the all BBs of n-homes and can be expressed as:

$$\sum_{j=1}^{n} P_{bb}(j) = \sum_{j=1}^{n} V_{bb}(j) i_{bb}(j) \tag{3}$$

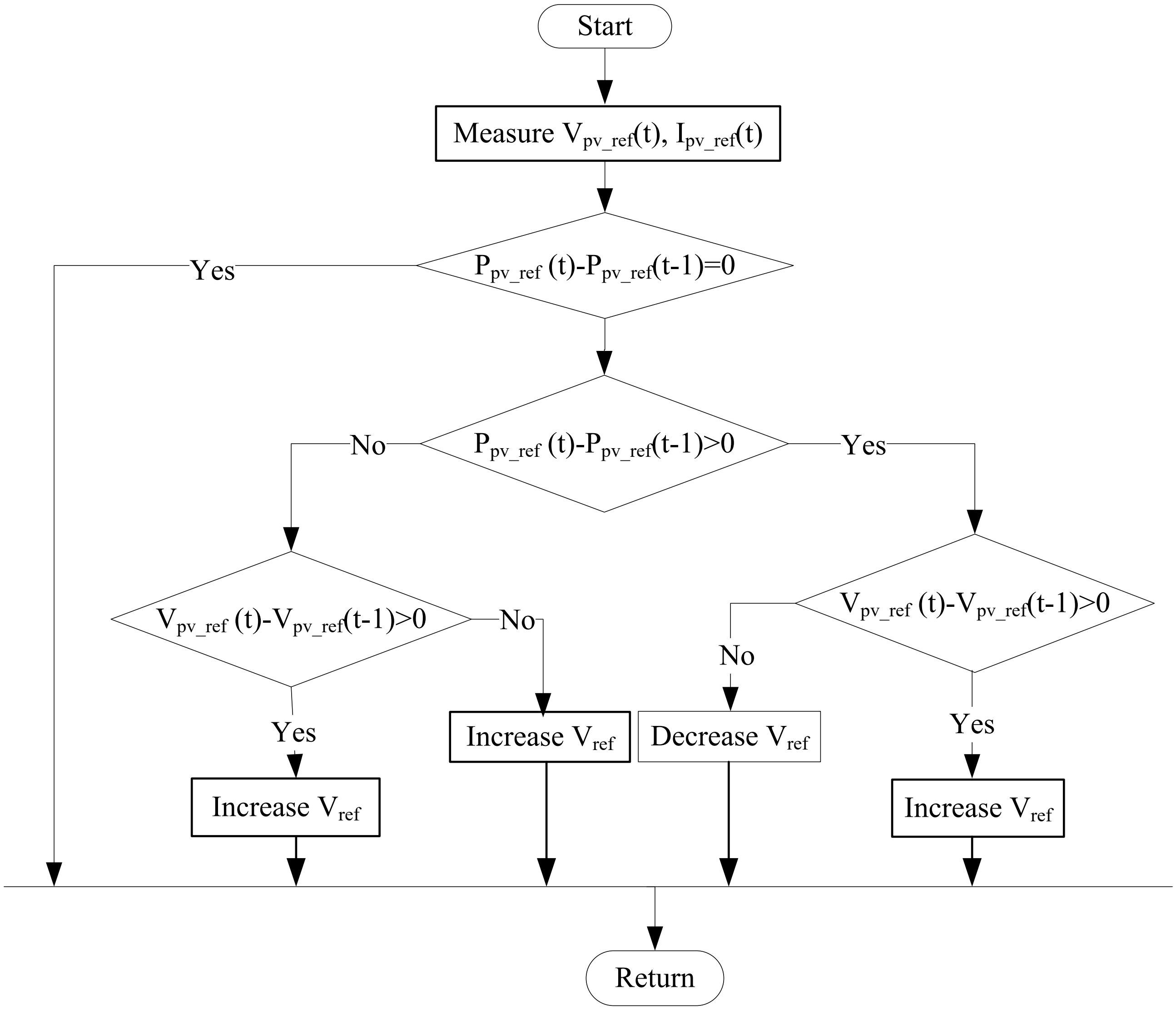

Fig. 2. Flow chart MPPT for maximum PV voltage

If the BB is not fully charged, the surplus power of the PV plants may be used for charging the BBs. Moreover if the demand is higher than the PV generations and PU is act as an outage power source the BBs will supply the surplus demand of the microgrid.

To get the maximum power production from the PV plant, the PV current has to be controlled by the controller (PI/FL-PI) near to its reference value (i_{pv_ref}) and the control equation is expressed as:

$$\sum_{j=1}^{n} i_{pv\_ref}(j) = \sum_{j=1}^{n} \frac{P_{pv\_ref}(j)}{V_{est\_pv}(j)} \tag{4}$$

where, V_{est_pv} is the estimated voltage of PV. The current is controlled with the capacitor value.

So, the estimated power (P_{est_pv}), can be obtained from the estimated PV current (i_{est_pv}), and estimated voltage of PV can be expressed as:

$$\sum_{j=1}^{n} P_{est\_pv}(j) = \sum_{j=1}^{n} i_{est\_pv}(j) V_{est\_pv}(j) \tag{5}$$

Likely, the estimated BB power (P_{est_bb}), can be obtained from the estimated BB current (i_{est_bb}), and estimated voltage of BB (V_{est_bb}), can be expressed as:

$$\sum_{j=1}^{n} P_{est\_bb}(j) = \sum_{j=1}^{n} i_{est\_bb}(j) V_{est\_bb}(j) \tag{6}$$

Now recalling the eq. (1), the controlled DC microgrid power (P_{dc_ref}), for controlled voltage can be obtained as in eq. (7)

$$P_{dc\_ref} = \sum_{j=1}^{n} P_{est\_pv}(j) \pm \sum_{j=1}^{n} P_{est\_bb}(j) \tag{7}$$

Here the meaning of positive sign is for when BB is delivering power to the load or it is going to discharge. The negative sign is for battery charging with the PV power. So a factor of charging battery is the power available from PV.

The controlled DC microgrid voltage (V_{dc_ref}), is obtained from controlled power (P_{dc_ref}) and from capacitor controlled current obtained (i_{dc_ref}) as:

$$V_{dc\_ref} = \frac{P_{dc\_ref}}{i_{dc\_ref}} \tag{8}$$

As the controlled voltage is obtained it is continuously going to maintain the grid power with the current changing by linear controllers placed in the microgrid and the controlled power is going to maintain the grid voltage.

IV. Simulation Results

The control of DC microgrid voltage is verified by the simulation results obtained in MALAB m-file environment. The performance of the voltage controllers are tested for the complete typical day with varying load conditions at different time instants. Results obtained from both the controllers viz. PI controller and FL-PI controller are shown in the following analysis. Let's consider that microgrid consists of four homes with PV captive power plant and PU. There is a PV plant of 5 kW, 4.5 kW, 4.75 kw and 6.5 kW installed in home-1, home-2, home-3 and home-4 respectively. The maximum demands of home-1, home-2, home-3 and home-4 are 10.32 kW, 10.88 kW, 10.13 kW and 6.49 kW respectively.

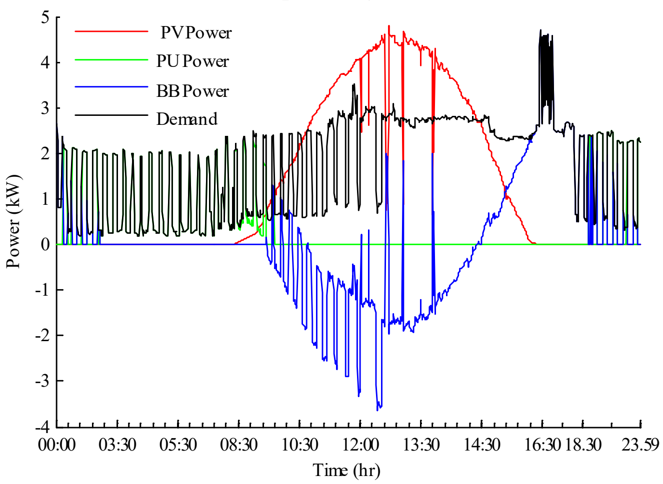

Fig. 3. Consumed power from different sources in a complete day

The power sharing of PV, PU and BB with DC microgrid including with the total demand connected to the modeled system is shown in Fig. 3. Here it is visible that the most of the power requirement is fulfilled by PV and PU. At the time instants when the PV power is higher than the demand then the surplus power is used to charge the BB. During 9:15-14:30hrs, the BB power is negative it means the BB is charging. During 14:30-16:40hrs time interval BB power is positive, it means BB is in discharging mode and supply the load with the PV and PU power curve remains at the zero level. Power available from PV (P_{pv}) is the function of available radiation ($\hbar$) from sun as:

$$P_{pv} = f\left(A, r, \hbar, \Upsilon\right) \tag{9}$$

where, A is the solar panel area, r is the solar panel yield, and (⍰) is the performance parameter of solar panel.

Further, during the 0:00-2:50hrs and 18:40-23:59hrs, the PV acts as outage power source and demand is higher than the BB load carry capacity so the BB feed the rated power and the surplus load is supplied by the PU. During 08:15-9:30hrs, the BB acts as outage source and PV power is smaller than the demand so the surplus power is balanced by the PU.

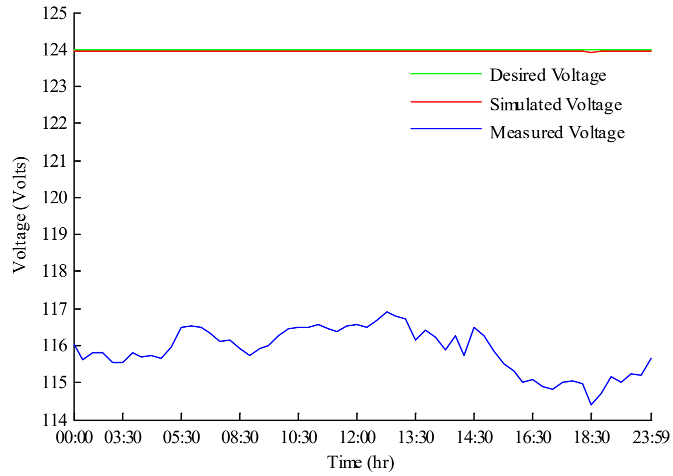

Fig. 4. PI controlled voltage for a complete day in a designed microgrid

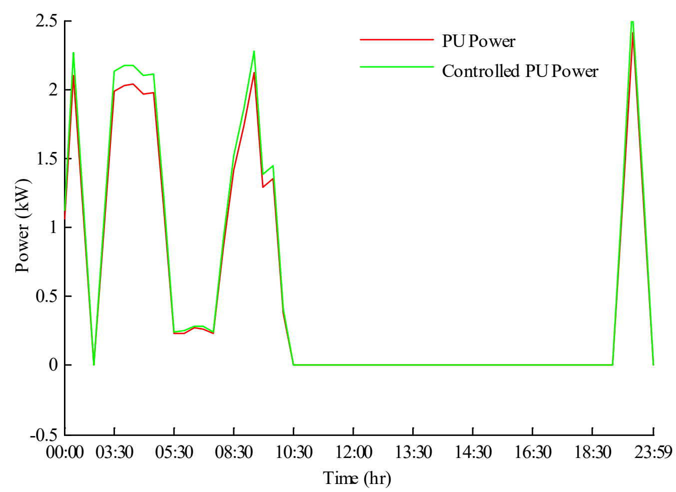

Fig. 5. PI controlled power corresponding to change in voltage

The controlled DC microgrid voltage and related power with PI controller during the complete day is shown in Fig. 4 and Fig. 5 respectively. It can be seen that load current changes with the change in microgrid power or vice versa, so the microgrid voltage also going to change accordingly. The controlled voltage approaches to its desired which is 124 volts from its measured value with the help of PI controller.

The voltage and power in the microgrid changes parallel as when there is a change in load current. It affects the power and then microgrid voltage will changes correspondingly. These changes in power can be noticed clearly in Fig.5.

The controlled DC microgrid voltage with FL-PI for a complete day is shown in Fig.6. There voltage fluctuation in the DC microgrid decreases significantly with the fuzzy-PI controller. The smooth microgrid voltage is obtained near to its desired value.

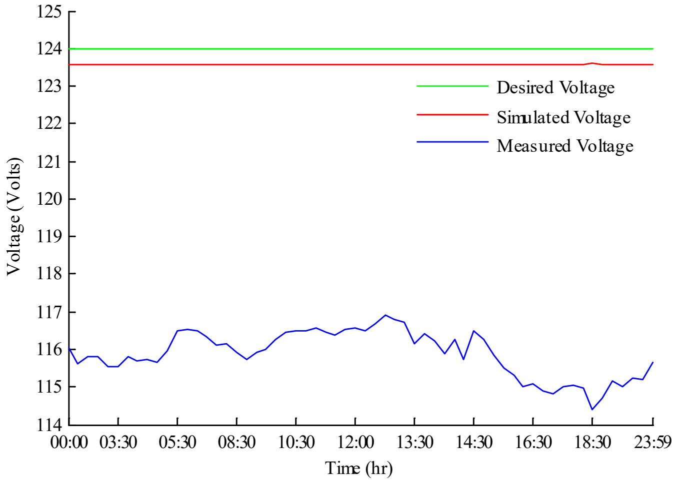

Fig. 6. FL-PI controlled voltage for a complete day in a designed microgrid

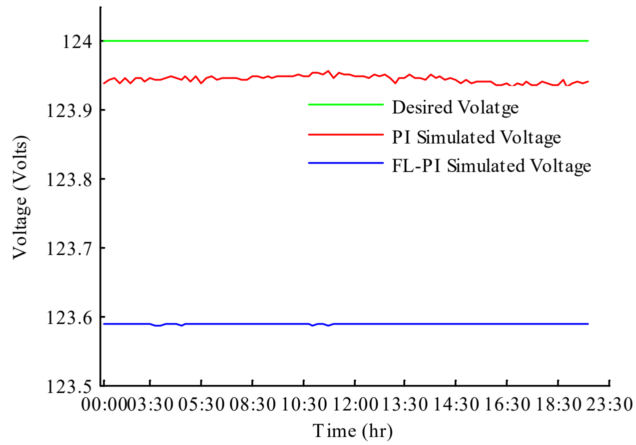

Fig.8. Simulated voltages obtained from PI and FL-PI

The changes in PU power corresponding to the voltage fluctuation in the DC microgrid with fuzzy-PI controller and without controller is shown in Fig. 7. It is worth to notice from Fig. 5 and Fig. 7 that there is almost similar power graphs obtained in both cases, as it is multiplication of current and voltage.

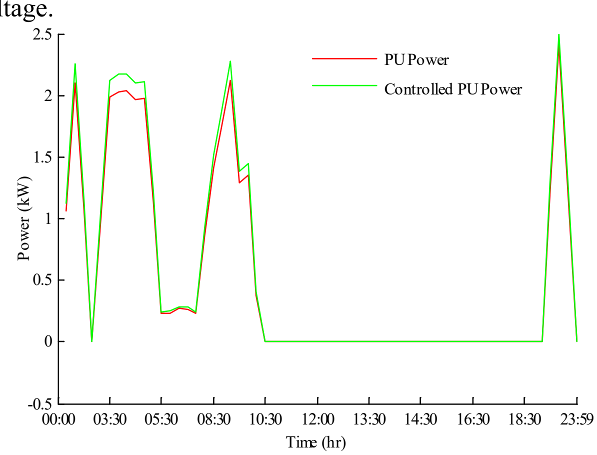

Fig. 7. FL-PI controlled power for change in voltage

A more clear impression of simulated voltages obtained from PI and FL-PI is shown in Fig. 8. The values of controlled voltage obtained in case of PI takes values near to 123.94 V and in case of FL-PI the values are near about 123.58 V. The trend line associated with FL-PI in the plot showing a near zero standard deviation i.e. a compressed variance. However in case of PI, the variance is spread out i.e. the values. The statistical analysis showing that the microgrid voltage is more stable in case of FL-PI controller. The values of standard deviation (σ), for PI and FL-PI are 5.1×10^{-3} and 5.1371×10^{-4} respectively with eq. (10).

$$\sigma = \sqrt{\frac{1}{t}\sum_{t=00:00}^{23:59}\left(V_t - V_{tmean}\right)^2} \tag{10}$$

where t is the time at different time instants of a typical day as t=00:00hrs, 3:30,………23:59, V_t is the simulated volatge at time instant t and V_{tmean} is the mean of the simulated voltage at time instant t.

The obtained time response parameters of the PI and FL-PI controller can be found in Table IV. The FL-PI controller is much better than the PI controller. Rise time is slightly high in case of FL-PI controller. But the settling time and steady state error is significantly small in comparison to PI controller. It verifies that the controlled voltage of DC microgrid with FL-PI controller has less fluctuation than the PI controller. The peak time is also small. The overshoot is case of FL-PI is very less, In case of PI the peak voltage around 162 volts i.e. around 38 volts more than the desired level however in case of FL-PI this value is nearly 140 volts i.e. 16 volts more than the desired level voltage. So the percentage overshoot is very less in case of FL-PI controller in comparison to the PI controller.

The proposed scheme avoids the drawback of the load sharing scheme or droop based control scheme with the utilization of the PI and FL-PI. Dynamic of the system has been improved.

TABLE I TIME RESPONSE OF THE DESIGNED CONTROLLERS FOR DC MICROGRID VOLTAGE

Controller Type	***Time Response parameters (Time in sec)***				
	Rise Time	***Settling Time***	***Over-shoot (%)***	***Peak Time***	***Steady state error (%)***
PI	0.0148	1.6091	0.326	0.47	0.9231
FL-PI	0.0264	1.3609	0.132	0.41	0.2325

V. CONCLUSION

The designed microgrid system is providing management between different sources viz. PU, PV, and BB. The energy is utilized to obtain the best performances of the energy sources. When there is left over energy after the demand, it is utilized to charge the battery. The BB is in use only when there is no source energy or less energy to fulfill the demand. So, the source efficiency is increased at an extent. The voltage controlling is tested with PI and FL-PI. Both controllers show fast and effective results, however the FL-PI leaves a good impact in the sense of performance parameters and good stability. Overall analysis of both the results is that FL-PI is superior and better for voltage stability of DC microgrid. The deviation from mean in case of PI is 10 times more than as in case of FL-PI i.e. showing more spread or variance. So FL-PI showing more stabilty.

REFERENCES

[1] R. Kadri, J. P. Gaubert, and G. Champenois, "An improved maximum power point tracking for photovoltaic grid-connected inverter based on voltage oriented control," *IEEE Trans. Ind. Electron.*, vol. 58, no. 1, pp. 66–75, Jan. 2011.

[2] E. Koutroulis and K. Kalaitzakis, "Design of a maximum power tracking system for wind-energy-conversion applications," *IEEE Trans. Ind. Electron.*, vol. 53, no. 2, pp. 486–94, Apr. 2006.

[3] J.C. Choi, H. Y. Jeong, D. J. Won, S. J. Ahn and S.I. Moon, "Cooperative voltage control of distributed generation and grid connected converter in DC microgrid," in *Proc. Int. Conf. on Renewable Energies and Power Quality*, Bilbao (Spain), vol.7, pp.1-5, Mar. 20- 22, 2013..

[4] Y. Ito, Y. Zhongqing, and H Akagi, "DC microgrid based distribution power generation system," in *Proc. IEEE Power electronic. and Motion Control Conf.*, Xian, vol. 3, pp. 1740-45, Aug 14-16, 2004.

[5] H. Kakigano, A. Nishino, and T. Ise, "Distribution voltage control for DC microgrid with fuzzy control and gain-scheduling control," *in Proc. IEEE 8th Int. Conf. on Power Electronic. and ECCE Asia*, Jeju, May 30-Jun. 3, 2011.

[6] B. Singh, A. Chandra, and K. Al-Haddad, "Computer-aided modeling and simulation of active power filters," *Elect. Mach. Power Syst.*, vol. 27, no.11, pp.1227–41, Oct. 2010.

[7] K. Chatterjee, B. G. Fernandes, and G. K. Dubey, "An instantaneous reactive volt-ampere compensator and harmonic suppressor system," *IEEE Trans. Power Electron.*, vol. 14, no. 2, pp. 381–92, Mar. 1999.

[8] S. Jain, P. Agarwal, and H. O. Gupta, "Design simulation and experimental investigations on a shunt active power filter for harmonics and reactive power compensation," *Elect. Power Compon. Syst.*, vol. 32, no. 7, pp. 671–92, Jul. 2003.

[9] F. Blaabjerg, R. Teodorescu, M. Liserre, and A.V. Timbus, "Overview of control and grid synchronization for distributed power generation systems," *IEEE Trans. Ind. Electron.,* vol.53, no.5, pp.1398–1411, Oct.2006.

[10] S. Buso, L. Malesani, and P. Mattavelli, "Comparison of current control techniques for active power filter applications", *IEEE Trans. Ind. Electronic.*, vol. 45, no. 5, pp.722-29, Oct. 1998.

[11] M. T. Ho, and C. Y. Lin, "PI controller design for robust performance," *IEEE Trans. Automatic Control*, vol. 48, no. 8, pp. 1404–09, Aug. 2003.

[12] P. G. Barbosa, L. G. B. Rolim, E. H.Watanabe, and R. Hanitsch, "Control strategy for grid connected DC-AC converters with load power factor correction," *Proc. Inst. Elect. Eng.—Gener. Transm. and Distrib.*, vol. 145, no. 5, pp. 487–91, Sep. 1998.

[13] H. Yu, J. Pan, and A. Xiang, "A multi function grid connected PV system with reactive power compensation for the grid," *Sol. Energy*, vol. 79, no. 1, pp. 101–06, Jul. 2005.

[14] G. Delille and B. François, "A review of some technical and economic features of energy storage technologies for distribution system integration," *Ecological Eng. Environ. Protection*, vol. 1, pp. 40–48, 2009.

[15] G. O. Cimuca, C. Saudemont, B. Robyns, and M. M. Radulescu, "Control and performance evaluation of a flywheel energy-storage system associated to a variable-speed wind generator," *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1074–85, Jun. 2006.

[16] H.Fakham, Di Lu, and B.Francois, "Power control design of a battery charger in a hybrid active PV generator for load-following applications", *IEEE Trans. Ind. Electronics*, vol.58, no.1, pp. 85-94, 2011.

[17] T. Zhou, and B. Francois, "Energy management and power control of a hybrid active wind generator for distributed power generation and grid integration," *IEEE Trans. on Ind. Electron.*, vol. 58, no. 1, pp. 95–104, Jan. 2011.

[18] W. Tang and R. H. Lasseter, "An LVDC industrial power distribution system without central control unit," in *Proc. IEEE Power Electronic. Specialists Conf.*, Galway, vol. 2, pp. 979–84, Jan. 18-23, 200..

[19] P. Karlsson and J. Svensson, "DC bus voltage control for a distributed power system," *IEEE Trans. Power Electron.*, vol. 18, no. 6, pp. 1405–12, Nov. 2003.

[20] D. Chen and L.Xu, "Autonomous DC voltage control of a DC microgrid with multiple slack terminals," *IEEE Trans. power syst.*, vol. 27, no. 4, pp. 1897-1905, Nov.2012.

[21] D. Salomonsson, L. Soder, and A. Sannino, "An adaptive control system for a DC microgrid for data centers," *IEEE Trans. on Ind. Appl.*, vol. 44, no. 6, pp. 1910–17, Nov./Dec. 2008.

[22] W. Xiao, W. G. Dunford, P. R. Palmer, and A. Capel, "Regulation of photovoltaic voltage," *IEEE Trans. Ind. Electron.,* vol.54, no.3, pp. 1365-74, Jun. 2007.

[23] R. K. Chauhan, B. S. Rajpurohit, and R. E. Hebner, "Voltage Standardization of DC Distribution System for DC Residential Buildings," in *Proc. 4th International Conference on Power and Energy Systems (ICPES),* IACSIT Singapore, Nov. 21-23, 2014.

VI. ACKNOWLEDGEMENT

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BIOGRAPHIES

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